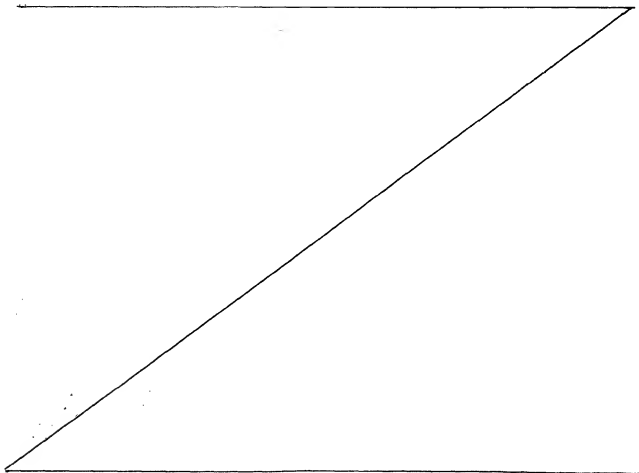


What Is Claimed Is:

1. A method for controlling a paper machine, comprising the steps of:  
solving difference equations obtained by differentiating heat-transfer equations that hold true among a steam drum, web and canvas;



predicting a dryer steam pressure after grade change; and

using said predicted dryer steam pressure as a dryer steam

pressure setpoint after grade change;

wherein the initial value of a web's moisture percentage at a dryer part inlet is calculated according to changes in a bone-dry coated weight and machine speed when solving said difference equations.

2. The paper machine control method of claim 1, wherein the initial value of said web's dryer part inlet moisture percentage after grade change is evaluated according to the following equation:

$$\text{initial value of web's moisture percentage} = MPNowInit + A_1 \cdot \frac{BD_2 - BD_1}{BD_1} + A_2 \cdot \frac{V_2 - V_1}{V_1}$$

where

$BD_1$  = bone-dry coated weight before grade change;

$BD_2$  = bone-dry coated weight setpoint after grade change;

$V_1$  = machine speed before grade change;

$V_2$  = machine speed setpoint after grade change; and

$A_1$ ,  $A_2$  and  $MPNowInit$  = parameters.

3. The paper machine control method of claim 2, wherein said parameters  $A_1$ ,  $A_2$  and  $MPNowInit$  are tuned according to the status of operation.

4. A system for controlling a paper machine, comprising:

an initial settings block for acquiring current operation status data and determining an incremental time interval for differential calculations from such data items as a machine speed and the circumference of a steam drum;

a moisture percentage calculation block;

a drying rate coefficient calculation block for evaluating a drying rate coefficient by simulation;

a steam pressure prediction block, to which the outputs of said initial settings block, said moisture percentage calculation block and said drying rate coefficient calculation block are applied in order to solve difference equations obtained by differentiating heat-transfer equations that hold true among a steam drum, web and canvas, and thereby predict a dryer steam pressure after grade change; and

a controller to which the output of said steam pressure prediction block is applied;

wherein said moisture percentage calculation block calculates the initial value of a dryer-part inlet moisture percentage used when said steam pressure prediction block solves said difference equations according to changes in a bone-dry coated weight and machine speed and said controller controls a paper machine using said predicted steam pressure output by said steam pressure prediction block as a steam pressure setpoint after grade change.

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5. The paper machine control system of claim 4, wherein the initial value of said web's dryer part inlet moisture percentage after grade change is evaluated according to the following equation:

$$\text{initial value of web's moisture percentage} = \text{MPNowInit} + A_1 \cdot \frac{BD_2 - BD_1}{BD_1} + A_2 \cdot \frac{V_2 - V_1}{V_1}$$

where

$BD_1$  = bone-dry coated weight before grade change;

$BD_2$  = bone-dry coated weight setpoint after grade change;

$V_1$  = machine speed before grade change;

$V_2$  = machine speed setpoint after grade change; and

$A_1$ ,  $A_2$ , and  $\text{MPNowInit}$  = parameters.

6. The paper machine control system of claim 5, wherein said parameters  $A_1$ ,  $A_2$  and  $\text{MPNowInit}$  are tuned according to the status of operation.

7. A method for controlling a paper machine wherein raw pulp is discharged onto a wire part, moisture contained in said raw pulp is removed by said wire part and by other means to form a web, said web is dried by a pre-dryer part and a size is applied to said web, and then said web is further dried by an after-dryer part so that a product is produced, comprising the steps of:

calculating the bone-dry coated weight of a size from the size's flow rate, size's concentration, size's specific gravity, machine speed, and web width;

evaluating said web's moisture percentage at an after-dryer part inlet after a size press from said bone-dry coated weight; and

controlling said pre-dryer and after-dryer parts using said evaluated moisture percentage.

8. The paper machine control method of claim 7, wherein said bone-dry coated weight of a size is calculated according to the following equation:

$$\text{size's coated weight} = CW = A \cdot (F \times S \times W) / (V \times d)$$

where

F = size's flow rate;

S = size's concentration;

W = size's specific gravity;

V = machine speed;

d = web width; and

A = constant;

said web's moisture percentage at an after-dryer part inlet after a size press is evaluated from said bone-dry coated weight; and  
said after-dryer is controlled using said evaluated moisture percentage.

9. The paper machine control method of claim 8, wherein an absolute

moisture percentage at said after-dryer part inlet after said size press is evaluated according to the following equation:

$$\text{web's absolute moisture percentage at after-dryer part inlet} = \{\text{absM}_0 + \text{CW} \cdot (100 - S) / S\} / \text{BD}_{\text{AFT}}$$

where

$\text{absM}_0$  = amount of moisture per unit area of web before size coating (calculation by simulation);

$\text{BD}_{\text{AFT}}$  = bone-dry coated weight at pre-dryer part outlet;

CW = size's bone-dry coated weight; and

S = size's concentration (%).

10. A system for controlling a paper machine, comprising:

a web production block for producing a web not yet subjected to size coating;

a pre-dryer part for drying said web produced by said web production block;

a size coating block for coating a size onto said web;

an after-dryer part for drying said size-coated web;

a moisture percentage calculation block for calculating the moisture percentage of said size-coated web; and

a controller, to which the output of said moisture percentage calculation block is applied in order to control said pre-dryer and after-dryer parts;

wherein said moisture percentage calculation block calculates the bone-

dry coated weight of said size according to equation 1 below, as well as the absolute after-dryer part inlet moisture percentage of said size-coated web according to equation 2 below:

$$\text{size's bone-dry coated weight} = CW = A \cdot \frac{F \times S \times W}{V \times d} \dots\dots\dots (1)$$

web's absolute moisture percentage at after-dryer part inlet =

$$\frac{\text{absMo} + CW \cdot \frac{100 - S}{S}}{BD_{AFT}} \dots\dots\dots (2)$$

$CW$  = size's bone-dry coated weight;

$F$  = size's flow rate;

$S$  = size's concentration (%);

$W$  = size's specific gravity;

$V$  = machine speed;

$d$  = web width;

$A$  = constant;

$\text{absMo}_o$  = amount of moisture per unit area of web before size coating  
(calculation by simulation); and

$BD_{AFT}$  = bone-dry coated weight at pre-dryer outlet.

11. A method for controlling a paper machine wherein raw pulp is discharged onto a wire part, moisture contained in said raw pulp is removed by said wire part and by other means to form a web, said web is dried by a pre-dryer and a size is applied to said web, and then said

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web is further dried by an after-dryer so that a product is produced, comprising the steps of:

calculating the predicted bone-dry coated weight of a size after grade change according to said size's bone-dry coated weight before grade change, said size's concentration before grade change, and said size's concentration setpoint after grade change; and

determining said web's moisture percentage after grade change at an after-dryer part inlet from said predicted bone-dry coated weight.

12. The paper machine control method of claim 11, wherein said predicted bone-dry coated weight of a size after grade change is evaluated according to the following equation:

predicted bone-dry coated weight of size after grade change =

$$CW' = CW \cdot \frac{S'_T}{S_T}$$

where

$CW'$  = predicted bone-dry coated weight of size after grade change;

$CW$  = bone-dry coated weight of size before grade change;

$S_T$  = size's concentration before grade change; and

$S'_T$  = size's concentration setpoint after grade change.

13. The paper machine control method of claim 12, wherein a dryer inlet moisture percentage after grade change is evaluated according to the following equation:

absolute dryer inlet moisture percentage =  $(\text{abs}M_0 + CW' \cdot (100 -$



$$S_r^*/S_r^*/BD_{ATT}$$

where

$absM_0$  = amount of moisture per unit area of web before size coating

(calculation by simulation);

$CW^*$  = size's predicted bone-dry coated weight after grade change;

$BD_{ATT}$  = bone-dry basis weight setpoint at dryer outlet; and

$S_r^*$  = size's concentration setpoint after grade change.

14. A system for controlling a paper machine, comprising:

a web production block for producing a web not yet subjected to size coating;

a pre-dryer part for drying said web produced by said web production block;

a size coating block for coating a size onto said web;

an after-dryer part for drying said size-coated web;

a moisture percentage prediction block for predicting the moisture percentage of said size-coated web; and

a controller, to which the output of said moisture percentage prediction block is applied in order to control said pre-dryer and after-dryer parts;

wherein said moisture percentage prediction block calculates the bone-dry coated weight of said size after grade change according to equation 3 below, as well as the after-dryer part inlet moisture percentage of said size-coated web after grade change according to equation 4 below:

$$CW' = CW \cdot \frac{S_r'}{S_r} \dots\dots\dots (3)$$

absolute after-dryer part inlet moisture percentage =

$$\frac{absMo + CW' \cdot \frac{100 - S_r'}{S_r'}}{BD_{AFT}} \dots\dots\dots (4)$$

where

$CW$  = bone-dry coated weight before grade change;

$CW'$  = predicted bone-dry coated weight after grade change;

$S_r$  = size's concentration before grade change;

$S_r'$  = size's concentration setpoint after grade change;

$absM_o$  = amount of moisture per unit area of web before size coating  
(calculation by simulation); and

$BD_{AFT}$  = bone-dry coated weight at dryer outlet.

15. The paper machine control system of claim 10 or 14, wherein the moving averages of measured values are used as the flow rate and concentration of said size.

16. The paper machine control method of claim 7, 8, 9, 11, 12 or 13, wherein the moving averages of measured values are used as the flow rate and concentration of said size.

17. A method for controlling a paper machine wherein a web is wound around steam drums of a steam dryer along with canvas so that said web

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is dried, and the steam pressure after grade change applied to each steam drum is predicted and controlled in order to change the moisture percentage of said web toward a given setpoint during grade change, comprising the steps of:

adopting thermal equilibrium equations between said steam drum and said canvas, between said steam drum and said web, and between said canvas and said web, and rewriting said thermal equilibrium equations into difference equations;

acquiring at least the steam pressure of said steam dryer, basis weight of said web, machine speed, and dryer part outlet moisture percentage of said web, by using sensors;

applying a value given by said equation cited in claim 9 as the initial after-dryer part inlet moisture percentage of said web, as well as other initial values, to said difference equations;

solving said difference equations repeatedly at a given time interval corresponding to a distance traveled by said web;

determining the drying rate coefficient of said web and a pattern of said web's steady-state moisture percentage transition along the direction in which said web moves within said dryer part, by repeating said solution step until a calculated final moisture percentage agrees with an actual measured value acquired with a sensor to within a given tolerance range;

acquiring at least the preset basis weight of said web, preset machine speed, and preset dryer part outlet moisture percentage of

said web as operating process variables after grade change when making a grade change;

applying a value or values obtained by using said method cited in claim 2 or 13 or both of said methods to said difference equations as the initial dryer part inlet moisture percentage of said web;

varying said steam pressure applied to each of said steam drums, in order to make said calculated final moisture percentage agree with said initial dryer part outlet moisture percentage to within a given tolerance range;

solving said difference equations repeatedly at a given time interval corresponding to a distance traveled by said web;

determining a pattern of said steam pressure applied to each of said steam drums along the direction in which said web moves; and

varying said steam pressure applied to each of said steam drums, so that the variation of said steam pressure agrees with said steam pressure pattern when an actual grade change is made.

18. A system for controlling a paper machine wherein a web is wound around steam drums of a steam dryer along with canvas so that said web is dried, and a steam pressure after grade change applied to each steam drum is predicted and controlled in order to change the moisture percentage of said web toward a given setpoint during grade change, comprising:

storage means for adopting thermal equilibrium equations between said steam drum and said canvas, between said steam drum and said web, and between said canvas and said web, and storing said thermal equilibrium equations as difference equations;

detection means for acquiring at least the steam pressure of said steam dryer, basis weight of said web, machine speed, and dryer part outlet moisture percentage of said web;

calculation means for applying a value given by said equation cited in claim 9 as the initial after-dryer part inlet moisture percentage of said web, as well as other initial values, to said difference equations, solving said difference equations repeatedly at a given time interval corresponding to a distance traveled by said web, and determining the drying rate coefficient of said web and a pattern of said web's steady-state moisture percentage transition along the direction in which said web moves within said dryer part, by repeating said solution step until a calculated final moisture percentage agrees with an actual measured value acquired with a sensor to within a given tolerance range;

setting means for acquiring and setting at least the preset basis weight of said web, preset machine speed, and preset dryer part inlet moisture percentage of said web as operating process variables after grade change when making a grade change;

input means for applying a value or values obtained by using said method cited in claim 5 or 14 or both of said methods to said

difference equations as the initial dryer part inlet moisture percentage of said web;

another calculation means for varying said steam pressure applied to each of said steam drums, in order to make said calculated final moisture percentage agree with said initial dryer part outlet moisture percentage to within a given tolerance range, solving said difference equations repeatedly at a given time interval corresponding to a distance traveled by said web, and determining a pattern of said steam pressure applied to each of said steam drums along the direction in which said web moves; and

variation means for varying said steam pressure applied to each of said steam drums, so that the variation of said steam pressure agrees with said steam pressure pattern when an actual grade change is made.